GLOBAL EFFECTS OF IMPACT EJECTA FROM THE K-T BOLIDE. James R. Lyons, Thomas J. Ahrens, Ashwin R. Vasavada, Division of Geological & Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

We consider here two aspects of the fine ejecta generated by the KT bolide. First, cratering scaling laws are used to estimate the mass of ejecta particles in the size range 1 μm - 10 mm with launch velocities consistent with ballistic trajectories, i.e., 5 - 11 km s^{-1}. For a 10 km diameter asteroid, impacting at 20 km s^{-1}, a global ejecta layer of 0.1 mm thickness is predicted, far less than the observed ejecta layer thickness of ~ 3 mm [5,6], indicating either a deficiency in the scaling laws or that a substantially (~ 30 times) more energetic impact occurred. Second, we evaluate the effect of near-infrared heating at the ground due to reentry of ballistic ejecta particles (consistent with a 3 mm ejecta layer) to determine whether this mechanism can produce global wildfires. The model includes heat conduction at the surface, and upward heat transport by atmospheric convection. For a 10 kW m^{-2} peak infrared flux at the ground [4], decaying with a timescale ~ 0.5 hour, the peak surface temperature predicted for a sand surface is 400 - 480 K, well below the wood ignition temperature of ~ 650 K [8], suggesting that fires were not ignited globally during ejecta reentry.

The semi-empirical formalism of O'Keefe and Ahrens [1] is used to compute crater ejecta mass, fragment size, and fragment velocity for the K-T impact. For cratering in the gravity-regime, we assume the cratering efficiency is that of wet sand [2], with the total ejecta mass given by

$$M_{ej} = 0.2\Pi_2^{-.65} M_i \qquad (1)$$

where $\Pi_2 = 3.22\, g a_i / v_i^2$ is the gravity scaling parameter for bolide radius a_i and velocity v_i. The cumulative ejecta mass with velocity > v is given by [1]

$$M_c(>v) = M_{ej}\left(v / v_{min}\right)^{-1.22} \qquad (2)$$

where $v_{min} \approx 0.5(gR_c)^{1/2}$ is the minimum velocity required for ejecta to escape a (transient) half-oblate spheroid crater of radius $R_c \approx (15M_{ej}/4\pi\rho)^{1/3}$ with ejecta density ρ.

From the distribution of ejecta fragments in ejecta blankets, O'Keefe and Ahrens [1] derive the cumulative mass fraction of fragments > mass m to be

$$f(>m, m_{bv}) = 1 - (m / m_{bv})^{1/6} \qquad (3)$$

where m_{bv} is the mass of the largest fragment with velocity v, obtained from

$$m_{bv} = m_b (v / v_{min})^{-3} \qquad (4)$$

An expression for m_b is given in [1]. For the ejecta velocities considered here, f for particles from 1.0 mm - 10 mm in size is ≈ 0.20. The total mass of ejecta particles between mass m_1 and m_2 and between velocities v_a and v_b is given by

$$M(v_a, v_b; m_1, m_2) \approx \left(M_c(>v_a) - M_c(>v_b)\right)$$

$$(f(>m_1, m_{bv}) - f(>m_2, m_{bv}))$$

The resulting total mass of ~ mm-sized ejecta particles is given in Table 1 for several possible K-T impact scenarios. Case I, a 10 km asteroid impacting at 20 km s^{-1}, yields a meager amount of ejecta (1.0 μm to 10 mm) with velocities in the range 5 - 11 km s^{-1}, enough for only a .09 mm global layer; the bolide mass alone yields a global layer 1.0 mm thick, assuming negligible loss by escape. Case II illustrates that a 20 km comet, with v_i = 60 km s^{-1}, and ρ_i = 1 g cm^{-3}, produces a 1.3 mm global layer of ejecta (1.0 mm to 10 mm), and a comparable layer of bolide material (assuming ~ 1/3 of the comet mass survives). By considering only shocked quartz, we can separate target rock ejecta from bolide material. Alvarez et al. [3] estimated that shocked quartz was produced for particle velocities in the range 1.6 - 4.5 km s^{-1}; higher velocities resulted in melt. In case III, we take this range of velocities and a particle size range from 0.1 to 1 mm, which, for a 10 km asteroid, yields enough shocked quartz for a 0.4 mm global layer, or for a layer several mm thick over North America.

To determine the ground temperature produced by the ejecta reentry heating mechanism of Melosh et al. [4], we solved the 1-D heat conduction equation subject to the surface boundary condition

$$-k\frac{\partial T}{\partial z} = (1 - A_{NIR})F_{NIR} - \varepsilon\sigma T^4$$

$$-\rho_a c_a u_* C^u (T - \theta_a)$$

where T is the surface temperature, k is the thermal conductivity of the ground, A_{NIR} = 0.3 is the near-infrared surface albedo, ε = 0.9, ρ_a and c_a are the density and heat capacity of the atmosphere, u_* is the friction velocity, C^u is the upward heat transfer coefficient, and θ_a is the potential temperature at the top of the boundary layer. For u_*= 0.3 m s^{-1}, C^u ~ .09 for a turbulent boundary layer [7]. From Melosh et al. [4], the heat flux is F_{NIR} = 10 kW m^{-2}. The computed surface temperatures are shown in Fig. 1 for sand and granite, and for convection and no convection. In all cases the peak surface temperatures are far below the ignition temperature of wood, ~ 650 K [8], suggesting that reentry of ~ 1 mm-sized ejecta did not ignite fires globally.

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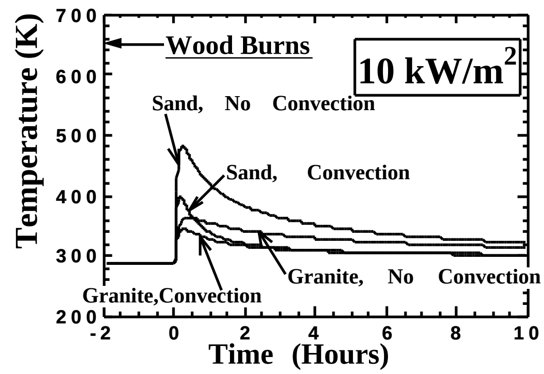

Figure 1. Computed ground temperatures for sand and granite surfaces, and for a peak near-IR flux of 10 kW m^{-2}. The importance of atmospheric convection is clearly illustrated. The predicted ground temperatures are much lower than that needed to ignite wood combustion.

Table 1. Total fine particle ejecta mass, not including bolide material.

BOLIDE	EJECTA MASS, g	GLOBAL LAYER, mm
I: 10 km ast., 20 km s^{-1}	2.0×10^{17}	0.17
II:20km comet, 60 km s^{-1}	1.7×10^{18}	1.3
III: 10 km ast., 20 km s^{-1}	1.8×10^{17}	0.14